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DIGITIZING AMERICAN MANUFACTURING

## DMDII FINAL PROJECT REPORT

PROJECT TITLE	
Principle Investigator / Email Address	General Electric Company (GE) acting through GE Global Research
Project Team Lead	Elastic Cloud-Based Make: Supply Chain Configuration Use Case
Project Designation	<a href="#">DMDII-14-09-02</a>
UI LABS Contract Number	0220160006
Project Participants	<a href="#">Rochester Institute of Technology</a>
DMDII Funding Value	\$499,903.00
Project Team Cost Share	\$499,903.00
Award Date	14 March 2016
Completion Date	May 2017

SPONSORSHIP DISCLAIMER STATEMENT: This project was completed under the Cooperative Agreement W31P4Q-14-2-0001, between U.S. Army - Army Contracting Command - Redstone and UI LABS on behalf of the Digital Manufacturing and Design Innovation Institute. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the author(s) and do not necessarily reflect the views of the Department of the Army.

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# **Elastic Cloud Based Make Supply Chain Configuration DMDII-14-09-02**

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Digital Manufacturing and Design Innovation Institute

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Project name: Elastic Cloud-Based Make Supply Chain Configuration    Contract Issuer: DMDII  
Project manager: Ben Beckmann    Project number: 0220150009  
Contract type: Best Effort  
Report date: 28-Apr-2016

## MANAGEMENT SUMMARY

The goal of the Elastic Cloud-Based Make Supply Chain Configuration project is to further demonstrate paths to commercialization for additional AVM tools throughout the extended supply chain, from SME suppliers through large manufacturers, using the AVM Foundry Configuration Engine integrated in the DMDII Digital Manufacturing Commons (DMC), the DMDII mechanism for disseminating tools developed under the AVM program.

### *General Electric*

GE continues to monitor subcontract work and continues program management pending transition of contract to DMDII (see CR2).

### *RIT*

RIT has the DARPA version of the AVM software up and running on a local machine without any errors. RIT is working with PSU-ARL to understand the source code and the software flow. RIT has opened discussions with PSU-ARL regarding utilizing the updated source code from other DMDII programs for this program so that interoperability of code is maintained. Effort during March was minimal and consisted of additional discussions with PSU-ARL and UI-LABS. PSU-ARL has offered to host RIT for a visit to walk through the software and answer questions. However, PSU-ARL has asked to delay the meeting until after any extension/program update has been received from either GE or UI-LABS. As this meeting will be critical to development, further evaluation and development of software will be kept to a minimum until after the meeting.

## KEY EVENTS

- Elastic Cloud-Based Make Supply Chain Configuration program contract awarded March 14, 2016 and signed March 21, 2016
- The official program kickoff meeting was held June 29, 2016
- Conference call with GE and Penn State to discuss API for Foundry Configuration Tools August 22, 2016

## MILESTONES

**Key Milestones Table (those that represent significant project progress)**

Id.	Title	Plan completion date	Forecast completion date as reported two months ago	Forecast completion date as reported last month	Current forecast completion date	Actual completion date
M1	Model Libraries integrated into DMC	9/15/2016	*	*	9/15/2016	
M2	Model libraries populated with pertinent components, processes and resources	12/15/2016	*	*	12/15/2016	
M3	Agents integrated and configurable within DMC with validation complete	3/14/2017	*	*	3/14/2017	
M4	Candidate assembly modeled using AVM tools	3/14/2017	*	*	3/14/2017	
M5. 1	Reman process description and cost estimates complete	3/14/2017	*	*	3/14/2017	
M5. 2	Candidate assembly remanufacturing modeled using AVM tools	3/14/2017	*	*	3/14/2017	
M6. 1	Kick-off meeting	3/21/2016	*	*	3/21/2016	6/29/2016
M6. 2	Mid-project review	9/15/2016	*	*	9/15/2016	
M6. 3	Final report meeting at DMDII	3/14/2017	*	*	3/14/2017	

Notes: Dates do not reflect requested no-cost extension requested from DMDII-UI Labs.

\* First monthly report

## DELIVERABLES

Id.	Title	Baselined date	Modified date	Completed date
D1.1	Application programming interface and DMC service for component model and component manufacturing model libraries	9/15/2016	3/15/2017	
D2.1	Augmented component model library and component manufacturing model library delivered through DMC	9/15/2016	3/15/2017	
D2.2	Report on further gaps in functionality of model libraries	12/15/2016	6/15/2017	
D3.1	Documentation of validation of agent simulation, including simulation results	12/15/2016	6/15/2017	
D4.1	DMC integrated software solutions to support supply chain configuration	3/14/2017	9/14/2017	
D4.2	Demonstration of improvements realized by SMEs and/or potential gaps in foundry configuration engine	3/14/2017	9/14/2017	
D4.3	Workshop to demonstrate usability of supply chain configuration	3/14/2017	9/14/2017	
D4.4	Documentation of supply chain configuration use case delivered through DMC	3/14/2017	9/14/2017	
D5.1	Remanufacturing baseline process description with different scenarios and associated component cost estimates	3/14/2017	9/14/2017	
D5.2	Remanufacturing component cost model documentation (allows for changing remanufacturing assumptions and estimating impact on component pricing/schedule)	3/14/2017	9/14/2017	
D5.3	Remanufacturing Component Model Library data for remanufacturing use cases	3/14/2017	9/14/2017	
D5.4	Documentation of use case delivered through the DMC including demonstration of improvements/risk reductions that could be realized by SMEs and/or potential gaps in foundry configuration engine for remanufacturing applications	3/14/2017	9/14/2017	
D6.1	Monthly technical reports and quarterly reports	Monthly/ Quarterly (M1'16- M12'17)	Monthly/ Quarterly (M1'16- M18'17)	
D6.2	Final technical report on supply chain configuration for new make and supply chain configuration for remanufacturing	3/14/2017	9/14/2017	

### Notes:

- D1.1 – D6.2 Planned completion dates obtained from contract assumed start date of 3/15/2016. Revised forecast dates represent shift of completion date to reflect actual contract signing date and start of program at GE.
- D1.1 – D6.2 Contract amendment #1 requested of DMDII extending contract period of performance to September 14, 2017. Deliverable forecast completion dates revised to reflect 6-month program shift forward.

## SCHEDULE

### Progress and Deviations from Plan

The Elastic Cloud-Based Make Supply Chain Configuration program contract was awarded March 14, 2016 and signed March 21, 2016. The program is scheduled to begin April 2016. Contract amendment #1 was requested of DMDII to extend contract period of performance to September 14, 2017. Deliverable forecast completion dates were revised to reflect a 6-month program shift forward.

## PROGRAM RISKS

### Risk and Opportunity Register

This may be attached to the report if it is tracked in a separate risk database. Make sure that this section, or the attachment, just contains the key project risks. If the risks are documented here, use the following format.

Id.	Description	Likelihood	Mitigation plan (what is being done to prevent the risk)	Contingency plan (what will be done if the risk occurs)	Potential impact (dollar / schedule / quality etc)
R6.1	Schedule Delay due to delayed start of ECBM project	High	Working with DMDII to extend contract to be coordinated with ECBM	Submitting program no-cost extension request to adjust program end-date to reflect delay in start of ECBM project	Schedule delay
R1.1	Inability to satisfy SME needs for relevant business problems	Low	Execute properly-designed API to ensure AVM tool conforms with SME input	Report tool issues	Limit in user adoption
R2.1	Model libraries insufficiently populated with relevant piece parts and subassemblies	Low	Work with relevant business unit to identify gaps and populate model libraries	Create placeholder parts for model libraries	Quality
R3.1	Agents in AVM toolset unable to find appropriate benchmark	Low	Constraint exploration to find agent issues; detailed in report for additional development	NA	Limit in user adoption
R3.2	Data Availability	Moderate	Work with GE business partners to gain access to data for a relevant candidate assembly	NA	Quality
R3.3	Limited schedule to interact with toolset after transition in ECBM program	Low	Interact with toolset in offline manner and transition use cases and models to DMC when toolset is transitioned	NA	Schedule delay
R4.1	Limited ability to apply AVM tools to use cases based on data availability	Low	Data simulation input generations will be created for data that is not readily available	NA	Schedule delay
R4.2	Complexity of candidate	Low	Select assembly with sufficient part diversity but manageable number	Model subset of parts/assemblies	Quality

	assembly requires greater modeling effort		of parts to be modeled		
R5.1	Limited ability to apply AVM tools to use cases based on data availability and limited remanufacturing scenarios	Moderate	Data simulation input generations will be created for data that is not readily available; remanufacturing scenarios can be detailed in a sensitivity analysis	Model subset of parts/assemblies	Quality

## METRICS

Id.	Title	As-Is Baseline	Project Goal	Actual
MM1	Simulation Model Construction Time	TBD (Task 3.1)	½ x current state	
MM2	SME Accessibility to Model Libraries	None	Online Access	
MM3	Ease of adding new parts to Model Libraries	None	<5 minutes for piece parts	

## FINANCIAL STATUS

The current project has a twelve-month term, starting on March 14, 2016. The contract for the project was signed on March 21, 2016. Below are the financials reported by month.

Month	Federal Funds	Cost Share	Expected Total	Actual by Month	Actual Total
MAR16	8,000	8,000	16,000	0	0
APR16	15,000	15,000	30,000	1,268	1,268
MAY16	30,000	30,000	60,000	580	580
JUN16	40,000	40,000	80,000	5,186	5,186
JUL16	50,000	50,000	100,000	5,081	5,081
AUG16	50,000	50,000	100,000	4,065	4,065
SEP16	50,000	50,000	100,000	22,678	22,678
OCT16	50,000	50,000	100,000	21,897	21,897
NOV16	50,000	50,000	100,000	29,222	29,222
DEC16	50,000	50,000	100,000	28,740	28,740
JAN17	50,000	50,000	100,000	*	*
FEB17	29,000	29,000	58,000	*	*
MAR17	28,000	28,000	56,000	*	*

\* No invoicing in 2017.

## CHANGE REQUEST HISTORY

CR Id.	Title	\$amount	Schedule change (if any)	Status (in review, agreed, withdrawn)	Comments
CR1	Program Start Date Change Request	0	Change Start Date on tasks from JAN15 to APR16	In Review	
CR2	Change of Program Management				GE is exploring transition of contract to DMDII

## TASKS

### Task 1—Integrate Model Libraries into DMC

#### Rationale

The AVM Tools for Foundry Configuration are of significant value to the manufacturing base. This project will integrate the Model Libraries included in the Foundry Configuration Engine into the DMC and provide an interface for SMEs to self-populate product catalogs to further enhance the commercialization of the Engine through the DMDII Digital Manufacturing Commons.

#### Approach

In this task, an API will be created for the Component Model Library and Component Manufacturing Model Library. The API will be used to create services that will be exposed through the DMC.

Task 1.1—Create APIs for Component Model Library and Component Manufacturing Model Library

Task 1.2—Publish DMC services for self-population of parts and assemblies to Model Libraries in DMC

#### Update:

1. GE
  - a. Model library API development continues.

### Task 2—Population of Model Libraries

#### Rationale

The AVM Tools for Foundry Configuration are of significant value to the manufacturing base. This project will populate the Model Libraries with parts and assemblies to further enhance the commercialization of the Engine through the DMDII Digital Manufacturing Commons.

#### Approach

In this task, the current data in the Component Model Library and Component Manufacturing Model Library will be assessed and gaps applicable to DMDII members will be identified. The libraries will then be further populated with applicable processes, resources, and part data.

Task 2.1—Assess Component Model Library, Component Manufacturing Model Library, and Manufacturing Model Library

Task 2.2—Further populate Model Libraries with pertinent components, processes, and resources

Task 2.3—Populate Component Manufacturing Model Library with models from aPriori Design for Manufacturability Assessment Tool data

#### Update:

1. GE
  - a. A population of candidate parts and sub-assemblies was identified and archived for populating the Library once DMC services from Task 1 are published.

### Task 3—Foundry Agent Simulation and Validation

#### Rationale

The AVM Tools for Foundry Configuration are of significant value to the manufacturing base. There are multiple agents within Agent System, including Foundry Agents, Product Agents, Buyer Agents, Manufacturing Agents, and Controller Agents. These agents combine to create a particular foundry configuration which is then simulated to verify the robustness of the manufacturing schedule by modeling

resource constraints and contention for capacity. This simulation is the final step in validating the candidate configurations of the supply chain to find the optimal configuration.

### Approach

In this task, a candidate assembly, provided by GE, will be identified and a benchmark process will be formulated. The team will then use the Foundry Agent Simulation, delivered through the DMC, to validate the candidate configurations and further demonstrate the speed and validity of using the Process Planning Engine.

Task 3.1—Create Benchmark Configuration using Existing Agents in Process Model<sup>[1]</sup>

Task 3.2—Implement and Validate Foundry Agent Simulation using Candidate Assembly

### Update:

1. GE
  - a. Meeting early October with RIT to discuss foundry configuration engine dataset requirements. Development tabled while waiting for software from PSU (ECBM deliverable) for creating simulation.

## Task 4—Use Case: Supply Chain Configuration for New Make

### Rationale

The AVM Tool Set for Foundry Configuration delivered through the DMC is a candidate capability to help large manufacturers and SMEs to assess the cost and lead time of a candidate assembly through modeling the entire supply chain, using the data provided in the Component Model Library, and simulating automated process plans that flow through the various agents in the Foundry Configuration Engine architecture. This task will demonstrate a path to commercialization for the AVM Foundry Configuration tools through the DMC.

### Approach

In this task, the candidate assembly used in Tasks 2 and 3 will be modelled using the AVM tools and the results will be compared to results from subject matter experts and best practices. To support the successful use of the AVM tools, a workshop will be held to bring together SMEs, manufacturers and supply chain professionals to demonstrate the usability of the DMC Supply Chain Configuration Engine. During the execution of the use case, AVM tool feature enhancements will be identified, evaluated, and upgrades will be made in accordance with the funding level. Additional requested features will be documented in the DMC.

Task 4.1—Program Management

Task 4.2—Modeling of Candidate Assembly using AVM toolset through DMC

Task 4.3—Validation of Candidate Assembly using AVM toolset through DMC

Task 4.4—Workshop to Demonstrate Usability of Supply Chain Configuration

Task 4.5—Documentation of Use Case delivered through DMC

## Task 5—Use Case: Supply Chain Configuration for Remanufacturing

### Rationale

The AVM Tool Set for Foundry Configuration delivered through the DMC is a candidate capability to help SMEs assess the cost and lead time of remanufacturing candidate assemblies. By modeling the entire supply chain, including highly stochastic processes such as tear-down, overhaul and remanufacturing of components and assemblies, SMEs can reduce their risks in commercial contracting with customers (e.g.,

DoD, infrastructure organizations, system integrators). This task will demonstrate a path to further commercialization for the AVM Foundry Configuration tools through the DMC.

### Approach

In this task, the remanufacturing of the candidate assembly used in Tasks 2 and 3 will be simulated using the AVM tools and the results will be compared to results from subject matter experts and best practices. During the execution of the use case, AVM tool feature enhancements will be identified, evaluated, and upgrades will be made in accordance with the funding level. Additional requested features will be documented in the DMC.

Task 5.1—Program Management

Task 5.2—Develop remanufacturing process baseline for candidate assembly, including component cost models

Task 5.3—Modeling of Remanufacturing Candidate Assembly using AVM toolset through DMC

Task 5.4—Documentation of Use Case delivered through DMC, Identification of gaps/opportunities for Remanufacturing Use Case

### Update

1. GE
  - a. N/A
2. RIT
  - a. Meeting with GE and Penn State early October to further discuss model library modifications for remanufacturing use case. Foundry Configuration tool should be available from PSU toward end of November.
  - b. Meeting with GE and Penn State October 19 to communicate model and software changes needed.

## Task 6—Program Management

### Rationale [SEP]

The Principal Investigator will monitor the development process to ensure all deliverables are being met on-time and on-budget [SEP]

### Approach [SEP]

The Principal Investigator will coordinate all tasks and reports. [SEP]

### Update

1. GE
  - a. The team continues to meet on a regular basis.



## Program Metrics



Metric	Present State (Baseline)	Future State (Project Goal)
Simulation Model Construction Time	TBD (Task 3.1)	1/2 x current state
SME Accessibility to Model Libraries	None	Online Access
Ease of adding new parts to Model Libraries	None	>5 minutes for piece parts

UI LABS Collaborator

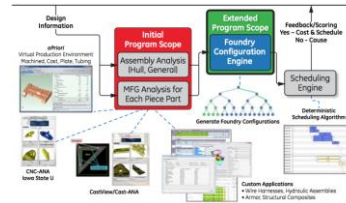
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## Products



- Transition of DARPA AVM Flexible Manufacturing Configuration Tools/Model Libraries to DMC
- Pre-population of model libraries in DMC
- Additional use cases for supply chain configuration published through the DMC

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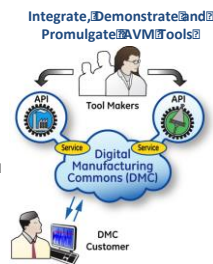
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## Project Benefits



- Provide end-to-end demonstration of mature AVM tools through DMC
- Provide demonstration of the application of supply chain configuration optimization for efficient remanufacturing
- Demonstrate usefulness of software to manufacturing community



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Risks



Task	Risk	Potential Impact	Mitigation
<b>Key Technical Risks</b>			
1	Inability to satisfy SME needs for relevant business problems	Low	Execute properly-designed API to ensure AVM tool conforms with SME input
2	Model libraries insufficiently populated with relevant piece parts and subassemblies	Low	Work with relevant business unit to identify gaps and populate model libraries
3	Agents in AVM toolset unable to find appropriate benchmark	Low	Constraint exploration to find agent issues; detailed in report for additional development
3	Data Availability	Moderate	Work with GE business partners to gain access to data for a relevant candidate assembly
4	Limited ability to apply AVM tools to use cases based on data availability	Low	Data simulation input generations will be created for data that is not readily available
5	Limited ability to apply AVM tools to use cases based on data availability and limited remanufacturing scenarios	Moderate	Data simulation input generations will be created for data that is not readily available; remanufacturing scenarios can be detailed in a sensitivity analysis
<b>Key Schedule Risks</b>			
3	Limited schedule to interact with toolset after transition in ECBM program	Low	Interact with toolset in offline manner and transition use cases and models to DMC when toolset is transitioned
<b>Key Cost Risks</b>			
4	Complexity of candidate assembly requires greater modeling effort	Low	Select assembly with sufficient part diversity but manageable number of parts to be modeled




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Timeline and Milestones








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Proposed Meeting Schedule



Topic	Lead Organizations	Fiscal Week	Focal Point
Remanufacturing Use Case Plans	RIT	28,30,32	Michael Hurston (RIT) Walter Gund (GE)



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## Appendix 2: RIT Status Update



GEGR PO#401048749

Update for month ending 31 March, 2017

Rochester Institute of Technology  
March 2017 Progress Report  
for work conducted in support of  
GE Global Research  
UI LABS/DMDII Elastic Cloud-Based Make (ECBM):  
Supply Chain Configuration Use Case Project

### High Level Technical Status

As previously reported, RIT has identified areas where the Component Model Library and iFAB tools would need modification to enable the tool to estimate time and cost for remanufactured components. The additional information falls under the following classes: core recovery, first pass inspection, disassembly, cleaning, post-cleaning inspection, processing (restoration), and final component inspection. Additionally, each component needs to track the percentage replacement expectations.

RIT has the DARPA version of the AVM software up and running on a local machine without any errors. RIT is working with PSU-ARL to understand the source code and the software flow. RIT has opened discussions with PSU-ARL regarding utilizing the updated source code from other DMDII programs for this program so that interoperability of code is maintained. Effort during March was minimal and consisted of additional discussions with PSU-ARL and UI-LABS. PSU-ARL has offered to host RIT for a visit to walk through the software and answer questions. However, PSU-ARL has asked to delay the meeting until after any extension/program update has been received from either GE or UI-LABS. As this meeting will be critical to development, further evaluation and development of software will be kept to a minimum until after the meeting.

### Project Risks and Opportunities

- This program relies on the ECBM project (DMDII 14-01-10). As such, progress on this program in the early stages has been slow due to the progress on 14-01-10. As previously discussed, a no-cost extension will be required to complete this program.
- The model libraries may only provide a piece of what is necessary for model development. The Foundry Configuration Tool will provide another piece; however, RIT intends to make changes to source code to extend the capability to cover remanufacturing. RIT will work with Penn State to ensure design decisions only add functionality without impacting the current functionality.



**GEGR PO#401048749**

**Update for month ending 31 March, 2017**

- The DARPA code base is currently being utilized by RIT; however, the iFAB software is being modified by PSU-ARL for the DMC implementation. RIT is awaiting a meeting with PSU-ARL to discuss the code to be modified under this program. This meeting is crucial to program execution and will be scheduled once an extension has been received.

### **Schedule Status/Modifications**

- A no-cost extension for the program through September 2017 and a revised spend plan was agreed upon between RIT and GE in the first month of the program. RIT has not yet received formal confirmation of the extension. As the program has been delayed awaiting meetings with PSU-ARL, RIT is anticipating an extension through 12/31/2017 will be needed.

### **Project Issues**

None identified

### **Budget Expenditure/Cost Share**

#### **Labor Hours**

Reporting Period	RIT	
	Planned	Actual
July	362	15
August	362	27
September	362	27
October	477	96
November	477	42
December	477	38
January	373	114
February	373	23
March	373	8
<b>Total</b>	<b>3,636</b>	<b>389</b>
<b>% Remaining</b>		91%

	Labor Hours
<b>Total Labor Expended to Date</b>	<b>389</b>
<b>Total Labor Hours Remaining</b>	<b>4,091.0</b>
<b>Total % Remaining</b>	<b>91%</b>